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ANALYSIS OF PRECISION MANUFACTURING PROCESSES THROUGH SIMULATION METHODS

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ABSTRACT-- *Modern technologies aid production system has become easier than ever before. Simulation helps in optimize the complication in the manufacturing processes. In this study we are using Tecnomatix product life management software to identify the bottleneck, throughput, buffer occupancy for the precision manufacturing process. Production line simulation has done for the discrete interval time i.e. Poisson distribution (λ) and Log-normal distribution (σ, μ). CNC machines are used in production line, for the same experiment were conducted to identify bottleneck in the continuous production process and different buffer occupancy and by detailed time study and process flow along the line. This paper aid to identify bottleneck operations and work in process status and proposes process changes for improve production efficiency. It helps in recognize the status of buffer for present machine efficiency for throughput improvement using design experimentation.*

Keywords-- *Bottleneck, Throughput, Machine efficiency, Buffer size, production line*

I. INTRODUCTION

Simulation aids in identifying bottlenecks in the production lines, workers requirement to operate machines and carry of parts. Many manufacturing problems can easy visualize and analysis using simulation methods. Buffer allocation gives optimal results in the closed production line, which is less effective to bottleneck analysis. Simulation experiments estimate the allocation capacity [1, 2] required for the production. Transitional buffers are helps to increase the throughput and utilization of machine. Placement of buffers can be done in parallel or series depending on the design of lines. Total buffer allocation and optimization will do by using algorithms with respect to cycle time. Optimization has done for the availability of machines in percentages, where machines are under maintenance to repair for certain duration. Effective simulation method use to identify the throughput [3] with respect to availability of machine in terms of percentage. Some authors determine the buffer allocation cost i.e. space worth for each pair of work stations for different environment conditions. Traditional practice in Indian manufacturing industries leads to non-value added waste present in production line can be eliminated by identifying the new design and development of flow processes. Sriram venumani et al. Investigate the importance of simulation to eliminate bottleneck and to improve production efficiency for discrete event simulation [4]. It helps in utilization of recourse in complex manufacturing situation. Julia Siderska, studied Computer simulations for various parameters where repetition process is occurred for several times. Simulation pointed that whole production process allowed to optimize parameters and increase in

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throughput [9]. Jingshan Li et al. Summarize the considerable procedure to deal the unpredictable machines and finite buffer capacity to throughput analysis in the automotive industry [8]. Design and operation management is a most strategic tool to deal real time data which helps to analyze the schedule of complex manufacturing systems. Lin Li et al. [13] compare the traditional approach and simulation for the production line to identify bottleneck, buffer size to minimize the non value added activities in production system. Mateusz Kikolski used plant simulation software to identify and eliminate bottleneck and to improve production efficiency and resource utilization [12] by eliminating waste by expanding production line for electrical manufacturing. Madhu Sachidananda et al. explore the discrete simulation application to improve throughput [11], better resource utilization and cost reduction. Sachin N K et al. presented the impact of simulation on manufacturing using tecnomatix software [10] and also exhibit the identification of problems in production system by analyzing various parameters. Yeong Wei Ng et al. Presented shop floor performance with respect to volume of parts and various pattern flows for components [15]. Emin Gundogar et al. explore the impact of dynamic situation to eliminate the bottleneck in manufacturing using theory of constraints using theoretical method [5]. M. Jahangirian et al. analyzed the impact of simulation for various production systems and also in business. It shows there was significantly helps entrepreneur to improve productivity and enhance their profits. [14]. Bottleneck was serious issue in all manufacturing industries, especially small and medium sectors, bottleneck was reduce the productivity, which leads to increase in defective items in production.

II. PROBLEM DESCRIPTION

Simulation is used to analyse the impact of bottleneck in the production line and buffer size on the overall throughput rate. Problems deals with identify bottleneck and suitable buffer size into buffer space in production line. Based on the objective function it is classified as follows:

i. To identify activities that causes bottleneck to the production line.
ii. To maximize throughput rate by eliminating bottleneck in the production line.
iii. To minimize capacity of buffer to attain necessary throughput.

In this description first we identify operation time and setup time (loading and unloading time of parts into the machine). For this, identifying bottleneck occurrence in the production line and how the buffer allocation will suitable to maximize the throughput rate. Actual production rate is not meet the customer demand due to less number of components has manufacturing. Hence it is difficult to maintain customer satisfaction. Using a Tecnomatix plant simulation, examine and validate the results for best buffer quantity in relation to throughput rate.

III. CASE STUDY

A. Simulation Model *of Production Line*

The production line model was dedicated to precision manufacturing of Multi-pin crank shaft, where most of the machines are CNC used for micro finishing to the component. In this production line have sixteen processes to complete the operations. Each processes of the production system surround a required number of resources. Production line simulation model was prepared with Tecnomatix PLM software 13.1 is as shown in figure.

Figure 1. Simulation model of Production line

For simulation of precision manufacturing line,it was assumed that the production line runs 6 days a week with three shifts per day. The total production time in the industry is 126 hours per week, same time has used for simulation in this work. Neglecting the operator's movement in the production plant during process also we are not concentrating on how to improve the overall equipment efficiency to increase machine availability efficiency. The model was prepared based on the real manufacturing company. The operating time of each machine are based on Log-normal distribution (μ, σ) and interval based on passion distribution (λ). Log-normal distribution is calculated as follows:

$$f(x) = \frac{1}{\sigma_0 x\sqrt{2\pi}} \cdot \exp\left[\frac{-\ln(x-\mu_0)^2}{2\sigma_0^2}\right]$$

Where σ and μ are respectively mean and standard deviations and are defined as follows:

$$\mu = \exp\left[\mu_0 + \frac{\sigma_0}{2}\right]$$

$$\sigma^2 = \exp(2\mu_0 + \sigma_0^2)\cdot(\exp(\sigma_0^2) - 1)$$

The maximum of the density function is defined as:

$$\exp(\mu_0 - \sigma_0^2)$$

The Poisson distribution is calculated as follows:

$$f(k) = \frac{\lambda^k}{k!}\,\mathrm{EXP}\,(-\lambda)$$

The operations time of each machine for the component production. Lower bound is the actual operation time upper bound has taken twice the lower bound is shown in Table 1:

Table 1. Operation and setup time of machines

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Machines	Interval time λ	Poisons distribution interval and Log-normal cycle time			
		Process time (mins)		Loading and unloading time (mins)	
		Lower bound	Upper bound	Lower bound	Upper bound
M1		8.57	17.14	0.20	0.40
M2		8.57	17.14	0.20	0.40
M3		4.50	9.00	0.10	0.20
M4		1.40	2.80	-	-
M5		1.50	3.00	0.15	0.30
M6		14.08	28.16	0.15	0.30
M7		13.04	26.08	0.15	0.30
M8		9.05	18.10	0.20	0.40
M9	5	35.08	70.16	0.20	0.40
M10		9.05	18.10	0.20	0.40
M11		2.00	4.00	0.10	0.20
M12		18.00	36.00	0.15	0.30
M13		3.00	6.00	0.10	0.20
M14		25.00	50.00	0.15	0.30
M15		7.50	15.00	0.10	0.20
M16		2.50	5.00	-	-

The production line consists of 16 work stations. The production line dedicated for the manufacturing of one types of product. Production layout is U shaped, so that workers can handle more than one operation. In the production analysis consider for three shifts, in all three shifts we have deducted lunch time and tea time i.e. 40 minutes. Data of the individual operation for production line is as shown in table 1.

The important step to analyzing the bottleneck of each work station is to determine the particular operations productivity. In this case of the operation in the work stations should be calculated using the formula

$$P_{ro} = \frac{tw-ts-tu}{tc}$$

Where: P_{ro} is work station productivity

t_w is working time of the shift

t_s is setup time of the workstation

t_u is unproductive time of the workstation

t_c is cycle time of the workstation

The buffer size was selected randomly, to see the throughput result. To identify the improvement in the production line for different buffer capacity size is as shown in Table 2.

Table 2: Random buffer size allocation (own study)

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Buffer	Exp 01	Exp 02	Exp 03	Exp 04
B_01	5	8	11	8
B_02	8	5	14	11
B_03	8	11	5	8
B_04	5	14	8	11
B_05	8	5	11	8
B_06	5	11	8	14
B_07	8	5	11	14
B_08	11	8	14	8
B_09	8	5	14	11
B_10	14	8	11	8
B_11	11	11	14	5
B_12	8	14	8	8
B_13	8	11	14	5
B_14	11	8	5	14
B_15	8	5	14	8
B_16	5	8	14	8

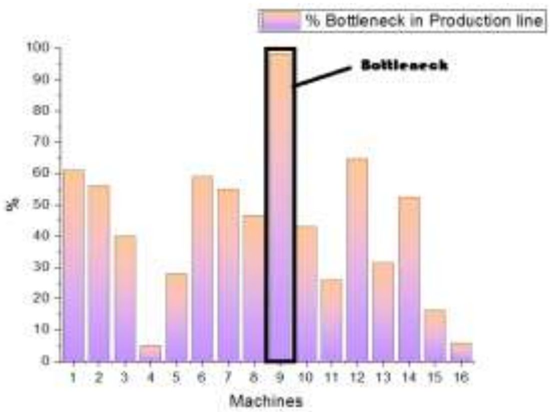
In the above table we have taken the size of buffer randomly and also considering the buffer for all sixteen workstations of the production line.

IV. SIMULATION OUTCOMES

Based on the simulation model, set of experiments for discrete event time i.e. working and setup (Table 1) was performed.

A. Bottleneck Analysis

It constrains the entire production system. Bottleneck can reduce or sometimes eliminate by adopting various methods. There is some possibilities to reduce bottleneck was add resources, minimize the downtime, increase the time of operation, ensuring the quality of product which machine has bottleneck etc. In bottleneck simulation we have consider single product, hence there is no other setup operation for another product.



(a)

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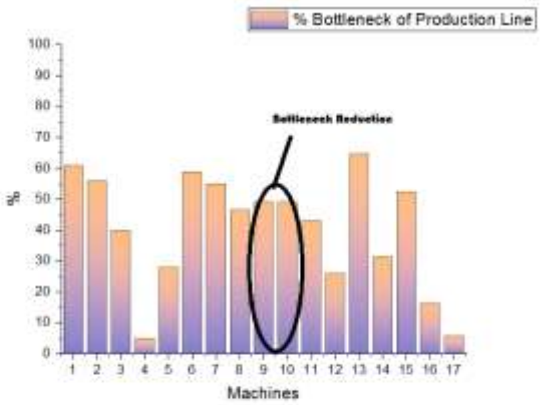


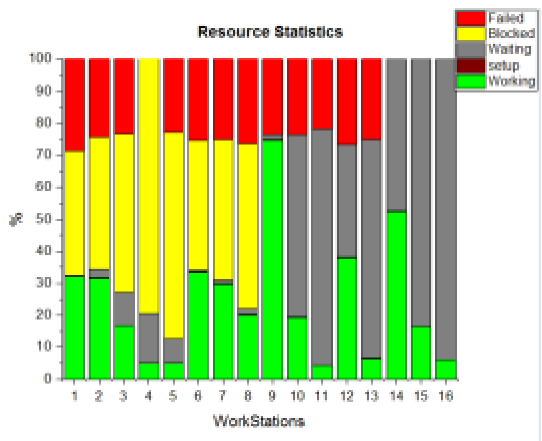
(b)

Figure 2. Bottleneck in production line (a) Before eliminating (b) After eliminating

These results showed to the simulation for 126 hours i.e. for week consideration. Fig shows the bottleneck in percentage for all machines. In real simulation model the actual output produced 194 units (not shown in simulation) above fig (a) shows the burden of all machines that take part during process. Analysis shows that Machine 9 is the bottleneck i.e. 90%. It occurs due to high operating time, it also cause the delay to corresponding machines. It emphases that one machine can resist entire production line throughput. Since it is CNC machine and the operating time cannot be reduced. Other possibility is to design a fixture to do process for two components at a time, but in existing CNC machine it is difficult to do. Shift can be increased but already we have allotted three shift, hence there is no room to do. Hence bottleneck is reduced by adding a machine to do same process as shown in fig. 1 (Expanding the production line).

Fig (b) shows the reduction in bottleneck percentage after adding one more machine (machine 10) to the bottleneck process (machine 9) so that bottleneck was reduced to 50%, which is aid to improvement in machine utilization.

Due to bottleneck in production line, machine utilization is less. Machine utilization directly impact on throughput rate. Each individual machine is important to get maximum throughput.



(a)

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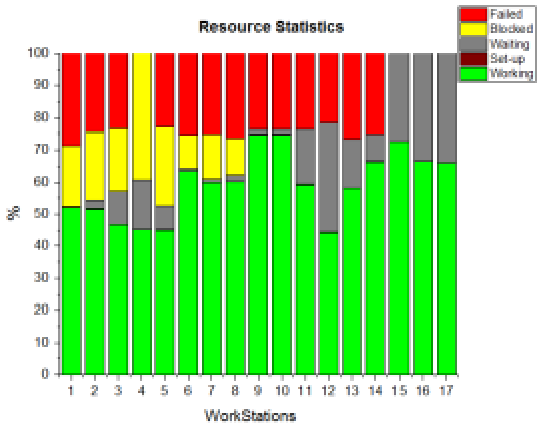

(b)

Figure 3. Machine Utilization of production line (a) before bottleneck (b) after bottleneck

Fig.3 shows the each individual workstation statistics. It clearly showing, bottleneck effects the machine utilization. In fig 3(a) due to high bottleneck percentage in machine 9, if affects the previous station i.e. less working and more blocked and in subsequently station was less working and high waiting percentage. Reduction in bottleneck increase the working, decrease in blocked and waiting percentage as shown in fig 3(b). As setup time is very less there is no significant impact in the production line. Also we can observe introducing a extra machine didn’t solve complete bottleneck problem, but it would have improve the smooth operation of the entire manufacturing. After reducing bottleneck there is 30-40 % improvement in production line utilization. Note that this scenario doesn’t consider the expanding cost (i.e. machine cost).

The throughput efficiency of the production line increased from 194 to 299 units during the 126 hours per week.

B. Buffer Analysis

Improvement in production line machine utilization is not only by expending the production line but also utilization of buffers in between the stations was also impact on increase in machine utilization percentage.

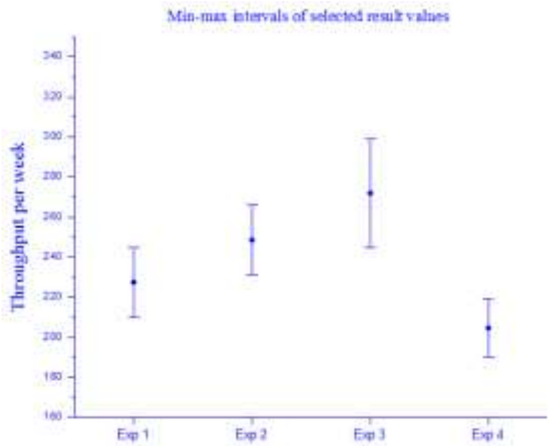

Figure 4. The throughput rate for random buffer size allocation (Table 2).

The Maximum throughput was obtained in Exp 3 (299 components per week) and the minimum throughput was obtained in Exp.4 (190 components per week). For regular interval time the maximum average throughput was 270 per week which was in Exp. 3. This due to in Exp 3, has higher buffer size as compared to others. Hence, there was significant improvement for higher buffer size. These results were not ultimate due to random buffer size allocation. There were some possibilities to improve the throughput rate by identifying the exact buffer size. Also we can eliminate or control the buffer inventory between stations.

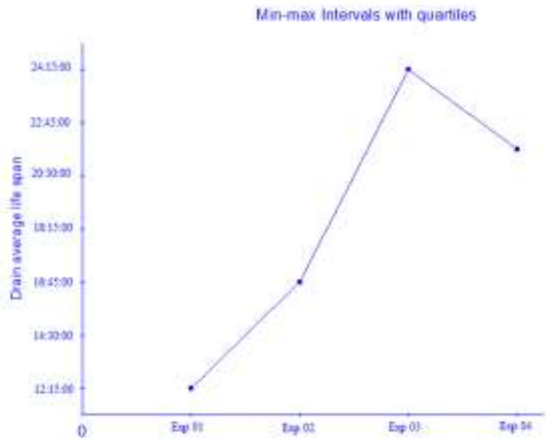

Figure 5. The average life span for throughput per week

The average life span estimates the how long the component (product) wait in the production system, it aid in identifying the level of WIP (work in process). The minimum average life span in the system was obtained for Exp 03 i.e. Maximum 299 units and the minimum span in Exp 01. Interestingly Exp 04 was obtained higher life span in system which less throughput rate as compared to Exp 01 and 02. Maximum throughput and average life span in Exp 03 indicates that, higher the buffer capacity gives very good results.

V. CONCLUSION AND FUTURE WORK

The simulation for the collected data shows the different indication to production line. Bottleneck problem is one of the major issues in any production system. This simulation experiments shows the individual workstation bottleneck percentage. It also describes the impact of bottleneck on overall throughput rate of production line. This report examine the actual efficiency of each machines by indicating working waiting, blocked and failed percentage of all machines. Bottleneck result shows, reducing the bottleneck of system improves the working time mean while reduce the blocking and waiting time. Allocation of suitable buffer improves the overall throughput rate of production system, also reduction in inventory. The higher buffer capacity shows better results for simulated production line. The general conclusions are as follows:

1. Reduction in bottleneck has significant impact on overall production throughput and also improves the machine utilization percentage.
2. The allocation of suitable buffer size between workstations has significant impact on throughput.

Further research could be doing for various models of the production system for different manufacturing sectors and the impact of man power utilization on the throughput rate of the manufacturing system.

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